Reducing maintenance costs using Machinery Management Systems

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Some call it asset management; others describe it as condition-based monitoring. Bently Nevada uses the term Machinery Management System (MMS) to denote a system engineered to help users proactively manage the operation and maintenance of reciprocating and rotating machinery. Plants have successfully reduced maintenance costs with effective predictive maintenance programs. However, to reduce costs further, a proactive, rather than a reactive, approach must be used. To achieve proactive machinery management, how the machine is operated must be combined with vibration and performance information. The Machinery Management System provides the tools to help understand the "mechanical health" of a machine and effectively manage its operation and maintenance requirements.

An MMS is composed of hardware (transducers, monitors, data acquisition "boxes," routers, hubs, computers, etc.) and software (data storage, analysis, display, import/export, communications, Decision Support℠, etc.) integrated into an overall plant information system (machine controls, plant controls, maintenance management, enterprise resource planning, etc.).

Anyone can buy all the various parts from vendors and connect them together. However, if it is not engineered as an integrated system, it will not work as a system and will provide limited value. An integrated MMS system is more than a system designed from an information systems viewpoint. It starts with machinery knowledge needed for proper transducer selection and ends with knowledge of how to apply the machinery information for improving machinery operation and maintenance.

An MMS engineered to best practices will provide information to accurately assess the condition of machinery. Knowing machinery condition allows operators and maintenance engineers to make decisions with confidence. There are three major stages in implementing an MMS: installing the infrastructure, integrating the information, and using the system to support team decision making.

Infrastructure

The infrastructure includes all the hardware and software that will provide and process the machinery information needed to assess condition. Many users think of the hardware as the protection system, transducers, and monitors. Transducer selection, location, and mounting are the most important parts of the hardware design. The wrong transducer, or the right transducer mounted incorrectly (or in the wrong location), is worse than bad data, as it can be bad data *that appears to be good data*. The measurements you need to manage your machine depend upon the design and construction of the machine and its criticality to your plant.

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Bently Nevada bases machinery condition assessment on making as direct a measurement as possible. That means – whenever possible – measuring rotor vibration by observing the rotor, casing vibration by observing the casing, and/or bearing vibration at the bearing. Sometimes, due to environmental considerations, an indirect measurement is

the only one possible. However, it is vital to understand the limitations of indirect measurements when assessing machinery condition and making machinery decisions.

The criticality or risk level is determined through a thorough risk assessment (see article on page 45). Critical machines require more measurements be taken more frequently than for low-risk machines. Critical machines require sufficient measurements, so problems can be analyzed, and possibly corrected, while the machine is still running. Low-risk machines do not need the same level of monitoring as critical machines. From an engineering principles standpoint, you would want to monitor low-risk machines the same way you would critical machinery. However, it is often difficult to provide the economic justification for that level of monitoring on low-risk machines. Consequently, machines in this category are frequently addressed with good success by using portable systems and periodic measurement. Significant maintenance cost reductions have been realized using portable data collection systems, because they can identify when machine failure will occur. However, they have an important limitation: they lack the frequency of data collection and the ability to correlate process information that is indispensable in *preventing* failures from occurring, and in understanding the conditions that lead to failure.

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To continue maintenance cost reductions, a different strategy is required – the adoption of a periodic online approach for monitoring low-risk machinery. This is especially true for machines that have been classified as "bad actors." A periodic online monitoring system for such machines provides the data resolution necessary for expanding measurement points to identify the fundamental causes of problems.

Transducer selection and location are based on the machine's design and operating characteristics. The minimum information for critical machines includes vibration information, machinery parameters (bearing temperatures, seal leakage, etc.), and process information. For low-risk machines that are connected to a periodic online data collection system, the goal is to choose enough transducers so operators can determine when the machine is being abnormally stressed. Process-related information (load, pressure, flow, etc.) should be available for easy correlation analysis and for online performance measurement. This allows operators to observe the changes in machine behavior as process conditions change. This direct feedback allows operators to adjust the process and extend machine life and can often be accomplished using fewer transducers than for critical machines. Low-risk machines that are not connected to a periodic online system should be monitored with portable equipment, since run-to-failure approaches can rarely be justified for any machine.

Machine protection systems

Machine protection systems are usually associated with critical and essential machinery categories. Protection systems shut down a machine or return it to a safe or nondestructive mode of operation without human intervention. They are used to ensure personnel safety, prevent catastrophic machine damage, and limit environmental impact. While it has been traditional to call these "machine protection" systems, that's somewhat of a misnomer. Why? Systems that rely on vibration amplitude alone may be able to protect the plant, its personnel, and the environment, by saving the machine from a catastrophic wreck. However, they rarely prevent the machine from damaging itself. Typically, by the time a machine is automatically shut down on amplitude alone, a considerable amount of damage has already occurred to bearings, seals, and other components where the machine's rotating and stationary parts are in close contact.

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The protection system should be robust enough to prevent false machine shutdowns (spurious trips), and to prevent missed machine protective action (missed trips). As well, the machinery protection system should be able to monitor and alarm on more than just overall vibration amplitude. Parameters such as 1X (running speed) amplitude and phase, 2X (two times running speed) amplitude and phase, NOT 1X amplitude (all vibration not occurring at running speed), and shaft position are available in the most advanced monitoring systems. This information

helps identify and flag machinery problems at an early stage of development. By monitoring more than just overall amplitude, you can help protect the machine itself.

Critical versus low-risk machines

While data acquisition (collecting and storing data) seems simple enough, it's important to again consider the machine characteristics and criticality. Critical machines and machines that can fail rapidly need continuous acquisition of data. If a bearing can fail in a few minutes due to lack of lubrication, it makes little sense to take data every hour or once or twice per month. After a machine trips, it's too late to think about data acquisition strategies. Consequently, all critical machines need a system that stores the data at high resolution prior to the trip and also captures it on alarm.

What about lower-risk machines? Where do they fit into an MMS? In many cases, there is an economy-of-scale that allows users to apply the same hardware as on critical machines. An MMS engineered for critical machines can also be economical for adjacent low-risk machines.

However, in many cases, the MMS must use a combination of data acquisition strategies. In any event, it should be engineered to integrate all the various data acquisition sources into a single view of the plant's machinery, and it should have provisions for entering other types of supplemental data, such as oil analysis, borescope pictures, thermography plots, etc.

While the purpose of an MMS is to manage the machinery assets to which it is connected, the MMS itself is an asset composed of transducers, wiring, sophisticated electronics, software, computers, and network hardware. As such, it requires maintenance and care as well. Often, users install all the infrastructure but fail to consider the

Shaft Position – A powerful machinery protection and management tool

Proximity transducers provide two measurements. The first, a dc voltage, represents the physical gap distance between the probe tip and the observed surface. The second, a dynamic signal, represents the vibration of the observed surface. The dc gap voltage is typically used for thrust position measurements. However, it is equally useful for radial position measurements of the journal in a fluid-film bearing. Unfortunately, many customers do not recognize the value of the dc gap measurement for journal bearings. The application of XY proximity transducers at the bearing permits measurement of the shaft centerline position within the bearing, relative to the geometric center of the bearing. This measurement, in conjunction with the known bearing clearance, provides a powerful machinery protection and management tool. Shaft vibration is important, but shaft radial position is equally important.

A recent case history demonstrates the value of the shaft position measurement. A hydrogen recycle machine train was recently shut down during a planned outage. During the shutdown, a low lube oil signal was to be simulated to verify that the control system would properly recognize this event and activate the relays. Unfortunately, an error was made in this procedure, and lube oil flow was actually shut off to the gearbox. Vibration levels increased during the shutdown. However, the gears and bearings were not inspected during this outage. The proximity probes' dc gap voltages had changed from –10 Vdc to –13 Vdc [indicating a change in position of at least .015 in or 15 mils (0.38 mm)]. This was not recognized as a need to inspect the gears and bearings.

The unit was restarted following the outage. The vibration levels exceeded the full scale (5 mils pp) monitor range. The unit was shut down again, and the bearings were inspected. The inspection revealed the loss of all babbitt material caused by the loss of lube oil during the previous shutdown. The gears were also damaged during this restart. Proper use of the dc gap voltage information would have prevented a permissive restart.

For many years, Bently Nevada has recognized the value of the dc gap voltage measurement. In addition to conventional radial vibration amplitude alarm capabilities, both our 3500 and 3300 Machinery Protection Systems also provide alarm setpoint and relay contact closure capabilities *that are based on a user-specified dc gap voltage limit*. This feature provides an additional machinery protection and management tool.

optimization and maintenance of the system. To make the task of managing the MMS easier, they must be sure to choose a system capable of monitoring its own integrity.

To summarize, the best practices for the hardware infrastructure are:

- Engineer it as an integrated system, not a collection of components.
- Select the right transducers. Then, locate and mount them properly.
- Understand the difference between machinery protection and plant/personnel/environmental protection when selecting a monitor.
- Choose a data collection and storage strategy that matches the machinery. Be sure to collect vibration, machinery parameters, and process data in a way that they can be correlated.
- Have a plan to care for all the assets in the infrastructure, including the MMS itself.

MMS information tools

There are three types of MMS information tools: those for analysis, those for Decision Support℠, and those for communications.

Analysis tools – the first step

Assuming the correct infrastructure is in place, an integrated suite of analysis tools provides the necessary data and plots to permit diagnosis of machine problems. These plots and data types include:

- Amplitude (direct, 1X, nX, NOT 1X).
- Phase lag.
- Frequency (full spectrum).
- Form (orbit/timebase).
- Position (shaft centerline, rod drop).
- Performance.
- Correlation of machine parameters and process data.

Many people start with a system that provides plots and data, and they typically derive excellent value from such a system. However, it is labor intensive. Its success depends almost entirely upon the availability of machinery engineers to analyze the collected data. A significant drawback of stopping at this level with an MMS is that, even if personnel are available to rigorously sift through all collected data, it still does not provide "real-time" Actionable Information℠ to plant operators. Plant operators are often the people in the best position to take early corrective action when machine problems begin to develop. It also does not make best use of available resources. People with expertise interpreting machinery data and plots are required to sift through all data *looking* for problems. Instead of concentrating on *correcting* known problems, they spend time looking for problems.

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Decision Support℠ tools – the second step

To move beyond the limitations of a system that provides only "data and plots," best practice is to take one more step and use a Decision Support tool. The use of the term "expert system" for such tools was a bit of marketing hype mixed with too much optimism. It implied that humans weren't required and that the system itself could take all necessary corrective actions when machinery problems arose. Bently Nevada instead chose to use the term "Engineer Assist™" for its first- and second-generation Decision Support systems. It was a better, more accurate term, but it kept this system out of the vision of some of the prime users: Operators, Maintenance Planners, and Plant Managers.

By using an online Decision Support tool, the productivity of specialist engineers is enhanced, and operators and maintenance engineers can access information in a way that's easy to use when making decisions. The Decision Support software evaluates the information using sophisticated rule sets, based on years of accumulated machinery diagnostics experience. Machinery and Maintenance Engineers no longer need to look at every machine using the analysis tool; the Decision Support system alerts them to changes in machinery condition, so they can concentrate on problems. Operators get Actionable Information℠, based on machinery condition and planned actions, based on previous operations and maintenance experience.

To provide even more value, the Decision Support software should allow for modification of its rules to fit individual machine applications and the direct experience of plant personnel. In addition, it should be easy to modify the suggested actions and the routing for messages, to meet specific plant operations methods.

Communications tools – the third step

The last information tool is a communications link to the analysis and the Decision Support software to allow off-site, in-house experts, machinery manufacturers, and engineering consultants, such as Bently Nevada, access to the information to support on-site

decisions. This capability to "dial in" also enables regular checks to determine if the system is operating properly and is optimized for your current operating situation.

To summarize, the best practices for information tools are:

- Engineer it as an integrated system, not a group of connected parts.
- Include analysis, Decision Support, and communication software tools.
- Ensure the analysis software provides the necessary plot and data types (amplitude, phase, frequency, form, position, performance, and correlation), and includes machinery parameters and process data inputs.
- Choose a Decision Support[SM] system that provides Actionable Information[SM] for everyone on the team (operators, maintenance personnel, machinery experts, and management).
- Perform a regular check to ensure that your system is operating correctly and is optimized for current conditions.

The dusty-key syndrome

Unfortunately, there are locations where fully capable MMS systems are in place but are not being used. It's what Bently Nevada has come to call the "dusty-key syndrome," symbolizing that the computer interface is never used and is collecting dust. This can be caused by many factors:

- The users bought it without understanding how to fit it into their decision making process.
- The system didn't include the Decision Support system, and the diagnostics expert has moved on to other responsibilities.
- The current users aren't the ones who purchased the system.
- There is no commitment to condition-based monitoring.
- The system was installed by the low bidder, or with part-time on-site maintenance support, and it isn't properly configured and optimized.

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Condition-based machinery management

The most important factor in using an MMS is being committed to condition-based machinery management as a part of an overall proactive maintenance program, such as Predictive Maintenance, Reliability Centered Maintenance, Total Productive Maintenance, Totally Integrated Maintenance, or a similar program.

Buy-in from everyone…

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Used by everyone…

Further to the statements above, the most successful users of an MMS are those who understand that an MMS is not a tool just for machinery experts. When best practices are followed and a Decision Support[SM] system is included in the MMS, it becomes a tool that Operations, Maintenance, and Management can use to provide the Actionable Information[SM] they need as part of daily and weekly decisions, as well as outage planning. It can provide the information needed to answer these types of questions:

- Are the machines in good enough condition to last until the next outage? Can the outage be postponed? With confidence?
- Can the fundamental cause of problems in "bad actors" be determined so they can become maintenance-free machines?
- Can process conditions or operating practices be changed to improve the life of the machine?
- Can the machine incur additional mechanical stress to give more output for the next week?

- Which parts are most likely wearing or failing? Can preparations for a shutdown be made by ordering parts that have long lead times?
- Can the machine be safely restarted after an unexpected trip?
- Can risk-based inspections be simplified by targeting problem areas and ignoring machines that are in good condition?

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Knowing your assignment and having the right people in place…

Another reason for the failure of MMS systems to provide value is failure to identify who is going to manage the machinery and who is going to maintain the MMS system itself. The return to core competencies for customers sometimes means staff has been reduced or reassigned to essential activities only, and the rest is outsourced. This may leave no one available to operate and maintain the MMS. An MMS must be well-maintained and optimized on a regular basis to provide accurate information and value. If the system is unreliable or provides inaccurate information, it isn't useable and provides no payback.

Sometimes all the information is available and it's accurate, but there is no one trained to use the information for decision making. This is becoming more of an issue as customers direct their limited people resources to spend more time on core business issues. Plant personnel can more effectively use the MMS if expert assistance from in-house experts, industry consultants, and machine manufacturers is quickly available through remote access. This allows outside expertise to be added to the in-house team when it's needed.

Adding knowledge to your system to stay current…

Even a comprehensive Decision Support℠ system can't always provide all the answers. Conditions change, new information is being collected all the time, and experience makes the operators and maintenance people more knowledgeable than any software program. Any MMS must allow operators, maintenance engineers, machinery experts, and machine designers the opportunity to customize the Decision Support system software to account for individual machines and local conditions and procedures.

Summary

The basis for effective use of an MMS is:

- Commitment to condition-based asset management.
- Integration of the MMS into the plant planning and decision making system.
- Condition-based maintenance of the MMS itself, including regular optimization.
- People trained in the use of the MMS as a Decision Support tool.
- Remote support from machinery experts and machinery designers as needed.
- Capability to customize Decision Support software to add new knowledge.

A properly-designed, installed, configured, and optimized Machinery Management System is a key tool for any proactive, condition-based maintenance program. The most important factor is a plant commitment to proactive asset management. No tools will be of value if the plant personnel are not convinced that a proactive approach provides a win for them as well as for the plant.

Bently Nevada provides these systems and has for many years. We have a wide range of services and products. This allows us to provide and install the necessary equipment, consulting, and training to ensure your plant personnel derive the most from the tools through proper operating procedures and practices. To learn more, contact your nearest sales or service professional.